PB-245 806

INTERIM STANDARDS REPORT BY THE COMMITTEE ON MOTOR VEHICLE EMISSIONS OF THE NATIONAL ACADEMY OF SCIENCES TO THE ENVIRONMENTAL PROTECTION AGENCY

National Academy of Sciences

Prepared for:

Environmental Protection Agency

April 1972

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Interim Standards Report

by the

COMMITTEE ON MOTOR VEHICLE EMISSIONS

of the

NATIONAL ACADEMY OF SCIENCES

to the

ENVIRONMENTAL PROTECTION AGENCY

National Academy of Sciences
Washington, D. C.

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NATIONAL ACADEMY OF SCIENCES

OFFICE OF THE PRESIDENT
2101 CONSTITUTION AVENUE
WASHINGTON, D C 20418

April 26, 1972

Sir:

I have the honor to transmit a report on Interim 1975 Motor Vehicle Emission Standards prepared in response to the request from the Environmental Protection Agency of March 2, 1972. This report summarizes the work and findings of the Committee with respect to this task.

We trust that this report will be of assistance to the Administrator of the Environmental Protection Agency in discharging his responsibilities under the Clean Air Amendments of 1970, Section 202(b)(5)(A).

Respectfully yours,

Philip Handler
President

The President of the Senate

The Speaker of the House of Representatives

The Administrator of the Environmental Protection Agency

NATIONAL RESEARCH COUNCIL

NATIONAL ACADEMY OF SCIENCES NATIONAL ACADEMY OF ENGINEERING

2101 CONSTITUTION AVENUE WASHINGTON, D.C. 20418

COMMITTEE ON MOTOR VEHICLE EMISSIONS
OF THE DIVISION OF ENGINEERING

TELEPHONE: 202-961-1621

April 26, 1972

Dr. Philip Handler
President
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D. C. 20418

Dear Dr. Handler:

On behalf of Dr. Ginzton and the Committee on Motor Vehicle Emissions, I hereby transmit to you the April 26, 1972 Interim Standards report from the Committee to be submitted to the Congress and to the Administrator of the Environmental Protection Agency.

Sincerely yours,

James E. A. John

James E. A. John
Executive Director
Committee on
Motor Vehicle Emissions

Interim Standards Report

Prepared by

THE COMMITTEE ON MOTOR VEHICLE EMISSIONS,
Division of Engineering, National Research Council,
in partial fulfillment of Contract No. 68-01-0402

between

THE ENVIRONMENTAL PROTECTION AGENCY

and

THE NATIONAL ACADEMY OF SCIENCES

National Academy of Sciences
Washington, D. C.

April 26, 1972

The study reported herein was undertaken under the aegis of the National Research Council with the express approval of the Governing Board of the NRC. Such approval indicated that the Board considered that the problem is of national significance; that elucidation or solution of the problem required scientific or technical competence and that the resources of NRC were particularly suitable to the conduct of the project. The institutional responsibilities of the NRC were then discharged in the following manner:

The members of the study committee were selected for their individual scholarly competence and judgment with due consideration for the balance and breadth of disciplines. Responsibility for all aspects of this report rests with the study committee, to whom sincere appreciation is expressed.

Although the reports of our study committees are not submitted for approval to the Academy membership or to the Council, each report is reviewed by a second group of appropriately qualified individuals according to procedures established and monitored by the Academy's Report Review Committee. Such reviews are intended to determine, inter alia, whether the major questions and relevant points of view have been addressed and whether the reported findings, conclusions, and recommendations arose from the available data and information. Distribution of the report is approved, by the President, only after satisfactory completion of this review process.

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1. INTRODUCTION

According to Section 202(b)(5)(A) of the Clean Air Amendments of 1970, if the Administrator of the Environmental Protection Agency (EPA) determines that a suspension of the 1975 light duty motor vehicle emissions standards required by paragraph (1)(A) for carbon monoxide (CO) and hydrocarbons (HC) should be granted "he shall simultaneously with such determination prescribe by regulation interim emission standards which shall apply (in lieu of the standards required to be prescribed by paragraph (1)(A)) to emissions of carbon monoxide or hydrocarbons (or both) from such vehicles and engines manufactured during model year 1975." Section 202(b)(5)(C) states that "any interim standards prescribed under this paragraph shall reflect the greatest degree of emission control which is achievable by application of technology which the Administrator determines is available, giving appropriate consideration to the cost of applying such technology within the period of time available to manufacturers."

In entering into a contract with EPA to carry out the study and investigation of technological feasibility called for by Section 202(c) of the Clean Air Amendments, the Academy agreed, at the request of EPA, to offer advice with respect to possible interim standards for the use of the Administrator if he found that a request for a suspension should be granted. By letter dated March 2, 1972, EPA asked the Academy for a report in April dealing with the question of interim standards so as to assist the Administrator in the event he decides to grant a one-year suspension in the effective date for the emissions standards pursuant to Section 202(b)(5).

The Committee notes that the three provisos stated in its report of January 1, 1972, namely, catalyst replacement and other maintenance, averaging of emissions of production vehicles, and availability of fuels with low levels of catalyst poisons, either have already been accepted by the Administrator or are being given serious consideration by him. The Committee also notes continuing progress by the manufacturers in emission control. Therefore, reiterating its earlier position, the Committee feels that, with these provisos, it is possible that the larger manufacturers will be able to produce 1975 model year vehicles that will meet the 1975 emission standards of the Act. The Committee, however, also reiterates its earlier position that it believes that the emission levels required in the Act will not be achieved by these vehicles in service unless regular, periodic maintenance of the emission-control system is required. This will necessitate the development and provision of suitable facilities, equipment, manpower, methods and perhaps legal procedures to accomplish this task. If in view of all the pertinent factors the Administrator decides to grant a one-year suspension for the 1975 standards, the Committee recommends that in setting interim standards he employ the methodology described in this report. Using data and other information that the Administrator determines is indicative of available technology, this methodology will yield specific values for interim standards.

The Committee chooses to present a methodology for the establishment of technologically feasible interim standards rather than to provide specific numerical values for such standards, because of the importance of using the most current data. Even in the relatively short period of time that will elapse between completion of this report and the date when a decision must be made on pending applications for suspension, the new test results which will become available to the EPA will considerably exceed the body of data, available at this writing, with which to determine both (a) whether it appears necessary to grant the requested suspensions and (b) if such suspension is deemed necessary, what interim emissions standards may reasonably be established. In order to establish the greatest degree of emission control that can be achieved at the present time, the most recent emission data obtained with test vehicles operated by the various manufacturers must be obtained and thoroughly evaluated.

The current hearings should provide the Administrator as complete and up-to-date a data base as can now be assembled. Application of the Committee's methodology to that data base should permit rational establishment of acceptable specific interim standards.

2. METHODOLOGY FOR DETERMINING INTERIM STANDARDS

Factors that must be considered in the development of interim standards that are technologically feasible for 1975 model year vehicles include: the emission control now being achieved on experimental prototypes of 1975 systems at low mileage, the expected deterioration in emission control over the 50,000 mile or five year "useful life" of the vehicle, slippage in emission control in transferring from experimental to production vehicles, manufacturing lead times and mass production capabilities, and the anticipated severity of performance and driveability problems.

Information now available for assessment of these factors consists of emissions measurements on different engines and vehicles using experimental control systems with presumed mass-production potential. Most of these vehicles have accumulated a few thousand miles or less. A small fraction of the vehicles have been tested over extended mileage, and the deterioration in emission control over 50,000 miles has been measured or can be estimated. In general, emissions increase over the first few thousand miles, and increase at a slower rate thereafter.

An appropriate equation for determining interim standards from such a data base is the following:

$$\text{Interim Standard} = \text{Emissions at 4,000 miles} \times \text{50,000-mile deterioration factor} \times \text{Production slippage factor}$$

The emissions at 4,000 miles are stated in grams per mile as determined by the 1975 Federal Test Procedure.* The 50,000 mile deterioration factor is defined as the emissions at 50,000 miles divided by the emissions at 4,000 miles.** As explained above, emissions at 4,000 miles times a 50,000-mile deterioration factor is the formula used by EPA to determine compliance of a manufacturer's production prototypes with the regulated standards. Deterioration results from both an increase in engine emissions and a decrease in catalyst efficiency. The deterioration factor and 4,000-mile emission should be determined from the same vehicle. However, while some vehicles with promising low-mileage emissions have been fully tested to 50,000 miles, most have not. It is necessary therefore to separate the two factors (4,000-mile emissions and 50,000-mile deterioration factor) to allow durability estimates to be made where 50,000-mile data may not be available or where the effect of catalyst replacement is to be determined.

The production-slippage factor allows for differences between the experimental and the production vehicle. This methodology assumes that pursuant to Section 206 of the Amendments only the average of emissions from a sample of production-line vehicles need meet the standards as

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* Federal Register, July 2, 1971.

**As defined in the Federal Register, November 10, 1970.

measured by the 1975 Federal Certification Test Procedure (the Warranty requirement of Section 207 applies to each vehicle). If all production vehicles must meet the interim standards, an additional factor must be included in the methodology, and higher interim standards would be set.

2.1 4,000-Mile Emission Values

Many considerations influence the choice of values for this analysis. The 4,000-mile HC and CO emission values could be set at the lowest values achieved by any manufacturer with one type of vehicle-engine combination. However, similar emission-control systems on different-sized engines in different vehicles exhibit different emissions levels. Also, the emission-control systems developed by the various manufacturers differ in their stages of development and emissions reductions achieved.

Choice of the single best car values could therefore result in a substantial limitation on the number of manufacturers able to meet the interim standards and on the number and types of engine produced. Choice of higher 4,000-mile emission values would allow a larger number of manufacturers and engines to comply. The question of production lead time is important here, since mid-1972 is about the time when major design details of the engine and emission-control system must be frozen for 1975 model year production. There is little time for manufacturers now achieving less than the required emission control to develop new components if they do not already have in-house experience.

It is important that the low-mileage emission values used to calculate interim standards be measured at about 4,000 miles if the EPA definition of the 50,000-mile deterioration factor is used. Emissions up to a few hundred miles are often significantly lower than values measured at 4,000 miles due to initial rapid catalyst deterioration. If emissions values measured at lower mileage are used, then the deterioration factor must be redefined accordingly.

The accuracy of these emissions measurements must be considered. Current estimates indicate a test-to-test variability of $\pm$ 20 to 30 percent on measurement of HC and CO emissions from 1975 experimental vehicles. Most of this variability is associated with vehicle operation, specifically a lack of repeatability in the function of some control-system components, such as the choke.

2.2 50,000-Mile Deterioration Factor

The present procedure for determining the deterioration factor during vehicle certification is to smooth the data by drawing a straight line through the measured emissions in grams/mile plotted against mileage over 50,000 miles. The deterioration factor is then emissions at 50,000 miles divided by emissions at 4,000 miles as indicated by the straight-line slope. A value for this factor is especially difficult to determine since the data are so limited and durability tests are not always done with the complete control system. Catalyst replacement, frequency and

nature of engine maintenance, levels of contaminants in the fuel, and vehicle usage affect the value of this factor.

Catalyst replacement is one practical way of reducing the deterioration in emissions control. If catalyst replacement is deemed acceptable by EPA, then a mechanism to ensure that such replacement takes place must be developed. Given the general public's current poor maintenance practices, merely including catalyst replacement at certain mileage (or time) intervals in the manufacturer's recommended maintenance procedures could not be expected to be fully effective, particularly since the level of exhaust emissions, as such, is not sensed by the driver from other aspects of engine performance. The criteria used to determine the basis for catalyst exchange and the replacement schedule will affect the value to be used for the deterioration factor.

The deterioration factors appear to depend on the emissions values achieved at low mileage with the system being tested. Thus due consideration must be given to the emissions levels of the vehicles used to determine a deterioration factor when the latter value is selected. The deterioration is due in part to a rise in engine emissions with mileage, as for example, carburetor adjustments and spark-timing change and deposits build up inside the engine. The major part of this deterioration is due to decrease in catalyst efficiency from contamination of the catalyst surface by poisons in the fuel and damage to the catalyst surface structure by overheating.

The magnitude of the deterioration in engine emissions is dependent on the durability of engine component settings and the maintenance carried out during the life of the vehicles. The deterioration of the catalyst depends on the purity of the fuel used throughout the vehicle's useful life. The data available on the effects of low concentrations of lead, phosphorus, and sulphur in "lead-free" gasoline are not yet sufficient to assess whether deterioration factors obtained to date will be realized in production vehicles using the fuel available in August, 1974. EPA has proposed regulated levels* of less than 0.05 grams lead per gallon and 0.01 grams phosphorous per gallon which are about twice the levels some automobile manufacturers and catalyst suppliers have suggested as desirable. The lower deterioration factors reported to date were generally obtained with fuels with contaminant levels less than the maximum allowable values proposed by EPA, typically at about half these levels. In the first year of wide availability of lead-free fuel, contaminant levels may be higher than regulated levels due to contaminants present in the supply and transfer equipment. If these levels do remain above the EPA regulated levels, it would be expected that deterioration factors would be higher than those which have been obtained to date with prototype engines and special fuels.

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*Federal Register, February 23, 1972.

Values for deterioration factors have ordinarily been obtained using the standard emission durability driving cycle.** In normal customer usage, vehicles are subjected to a broader range of driving patterns and the effect on the durability of these 1975 prototype emission control systems has not been ascertained. A large increase in engine emissions due to malfunction can also permanently damage the catalyst.

To calculate deterioration factors in emission control systems in which catalysts are replaced at specified intervals, an estimate must be made of the magnitude of the increase in engine emissions during 50,000 miles, since engine emissions determine the loading on the catalyst. Thus, as engine emissions steadily increase during the 50,000 miles, catalyst replacement at 25,000 miles will result in an effective exhaust emissions increase during 50,000 miles which is greater than half of the increase without catalyst replacement.

2.3 Production Slippage Factor

Past experience with emission control systems on experimental prototypes of current new production vehicles has shown that production-line versions of the control systems will not perform quite as well as experimental prototypes that have been hand-tailored. In part, this is due to minor changes in design to improve mass producibility and in part to stack-up of materials and dimensional tolerances.

The allowance made varies among manufacturers depending on their experience with current systems whose emissions are substantially higher. The values assumed range from 10 percent slip (factor of 1.1) to 30 percent slip (factor of 1.3). This factor is not as large as the other factors involved.

**Federal Register, November 10, 1970.

3. SAMPLE CALCULATION

To provide an example of the application of the methodology described in the previous section, the Committee will use the recent data available to it from the major American automobile manufacturers and one of the leading catalyst suppliers. The sources of these data are given in an appendix to this report. The two factors that need to be obtained from these data are 50,000-mile deterioration factors and the emissions at 4,000 miles.

In determining 50,000-mile deterioration factors the only data used were for cars that had completed close to 50,000 miles with no major change of components in the emission-control systems. For these data, the fuel-contaminant levels were generally about half of the EPA proposed levels. Figures 1 and 2 show 50,000-mile deterioration factors for HC and CO plotted against emissions at 4,000 miles.

In order to determine values of emissions at 4,000 miles, data from 55 promising vehicles were analyzed. The data sources are given in the appendix. These vehicles were considered promising because each had had at least 1,000 miles of durability testing without failure. Emissions measurements were taken on only a few of the vehicles at the 4,000-mile point; some durability tests have not yet extended beyond 1,000 miles, others did not involve emission measurements until well over 4,000 miles. For this reason, values quoted here for 4,000-mile emissions were taken at the measurement mileage closest to 4,000 miles, ranging from 1,000 miles for some tests to over 7,000 miles for others. In some cases, emissions measurements were taken on vehicles that were continually maintained during the mileage accumulation, including changes in carburetors and other components, engine tuneup, and other maintenance. In other cases, no maintenance was allowed during the mileage accumulation. A range of engine sizes is involved in the 55 vehicles, from 2-liter (122-cubic-inch) displacement to 472-cubic-inch displacement. The data available were not sufficient to establish definitive trends of emissions with engine sizes. Some emissions data on the 55 vehicles were taken with the 1975 CVS-CH test procedure, some with the 1972 CVS-C procedure. Finally, the fuel-contaminant levels for the 55 vehicles were not uniform. For example, some vehicles ran on lead-sterile fuel, others on fuels with lead levels approximately those of the 1974 EPA requirements. Further complicating evaluation of these factors is the aforementioned $\pm$ 20 to 30 percent variability inherent in the emissions measurement itself.

With all these reservations, it is still of interest to examine the results from the 55 promising cars. Emissions data have been classified by ranges and shown in the histogram of Figure 3. These data indicate that a few of the best cars, with high-purity fuel and one or two catalyst replacements, would come close to the 1975 standards.

The median emission values of the 55 promising experimental vehicles lie in the range of 0.4 to 0.5 grams per mile for HC and 3 to 4 grams per mile for CO. Caution must be exercised in the use of these data in this manner; vehicles with low HC emissions are not necessarily the same as those with low CO emissions. Thus, only 14 cars of the 55 cars have both HC emissions less than 0.4 grams per mile and CO emissions less than 3 grams per mile. If 4,000-mile emissions of 0.4 grams per mile for HC and 3 grams per mile for CO are used in the methodology for developing interim standards, deterioration factors of approximately 2.5 for both CO and HC are found in Figures 1 and 2 with no catalyst change. If a slippage factor of 1.1 is used, then a median car of this group should meet interim standards of approximately 1.1 grams per mile for HC and 8.2 grams per mile for CO.

With one catalyst change at 25,000 miles, the deterioration factor would be somewhat less. If all the deterioration were due to the catalyst, then catalyst replacement at 25,000 miles would give an effective deterioration factor over 50,000 miles of 1.75 for HC and CO. But this over-estimates the effect of catalyst replacement; engine emissions deteriorate as well. If it is assumed that the emissions would rise by 20 percent due to deterioration in engine adjustments alone, effective overall 50,000-mile deterioration factors with one catalyst replacement would be approximately 1.9 for HC and CO. With one catalyst change and a deterioration factor of 1.9, the median vehicle should meet interim standards of 0.8 grams per mile for HC and 6.3 grams per mile for CO.

Table 3.1

Comparison of Sample Calculation with Federal Emission-Control Requirements

Emissions (grams per mile)	Federal Requirements 1972-74*	Federal Requirements 1975**	Example Interim Standard Calculation**	
			One catalyst change	No catalyst change
Hydrocarbons	3.4	0.41	0.8	1.1
Carbon Monoxide	39.0	3.4	6.3	8.2

A comparison of interim standards as calculated from the example with the federal emission-control requirements for 1972 and 1975 vehicles is given in Table 3.1. The Clean Air Amendments of 1970 call for a reduction of at least 90 percent from emissions of CO and HC, allowable under the standards for light-duty vehicles manufactured in 1970. The values of interim standards from the sample calculation with one catalyst change call for reduction from the 1970 base line of 80 percent in HC and 81 percent in CO. If emissions from the uncontrolled car are used as a base

*CVS-C test procedure
**CVS-CH test procedure

line, the 1975 requirements represent a 97 percent reduction of HC emissions and a 96 percent reduction of CO emissions; the interim standards from the sample calculation with one catalyst change represent a reduction of 95 percent in HC emissions and 93 percent in CO emissions.

It is emphasized that the sample calculation presented in this section is for illustrative purposes only. In applying this methodology the Administrator would be expected to employ the most recent data available.

FIGURE 1

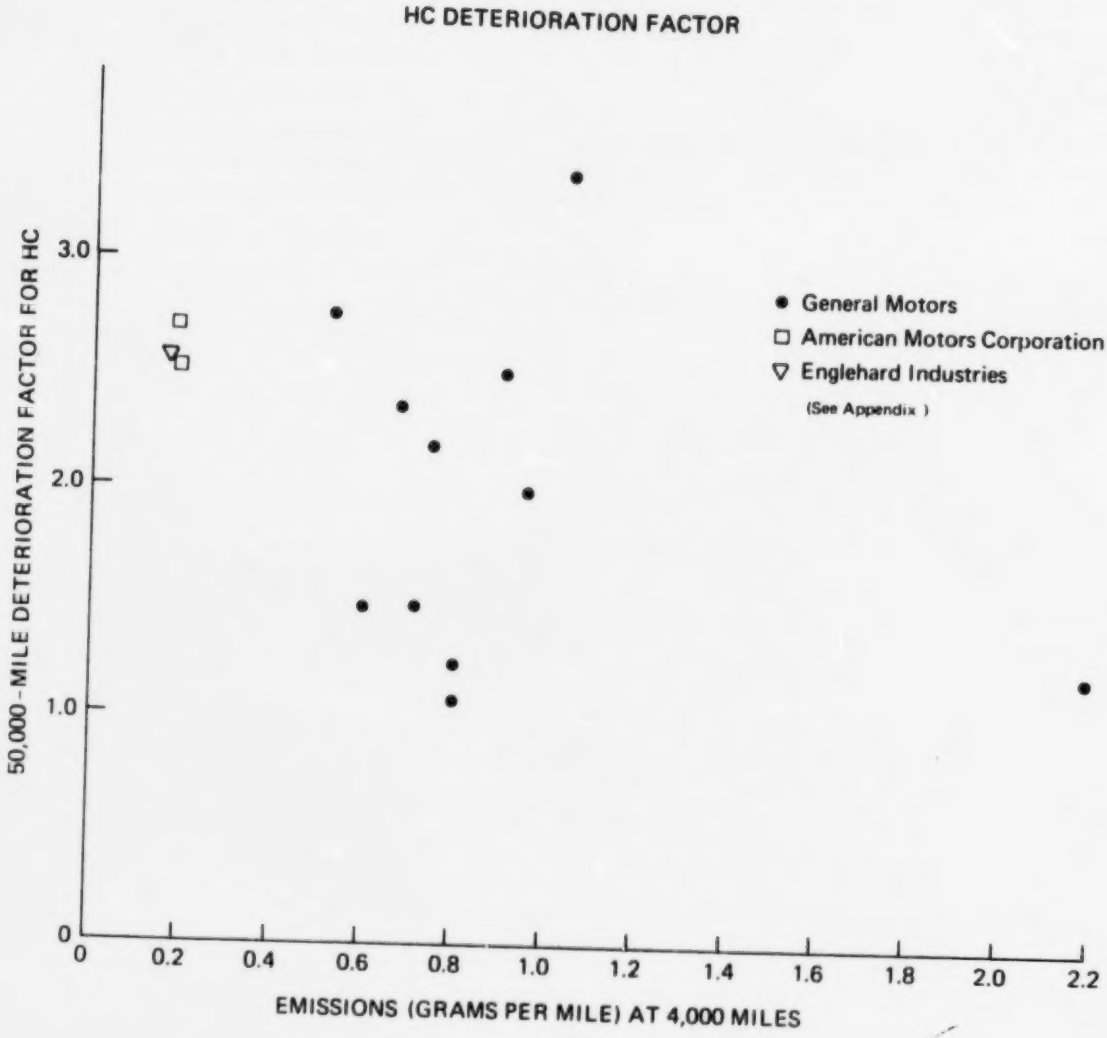

HC DETERIORATION FACTOR
50,000-MILE DETERIORATION FACTOR FOR HC
3.0
2.0
1.0
0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
1.6
1.8
2.0
2.2
EMISSIONS (GRAMS PER MILE) AT 4,000 MILES
General Motors
American Motors Corporation
Englehard Industries
(See Appendix)

FIGURE 2

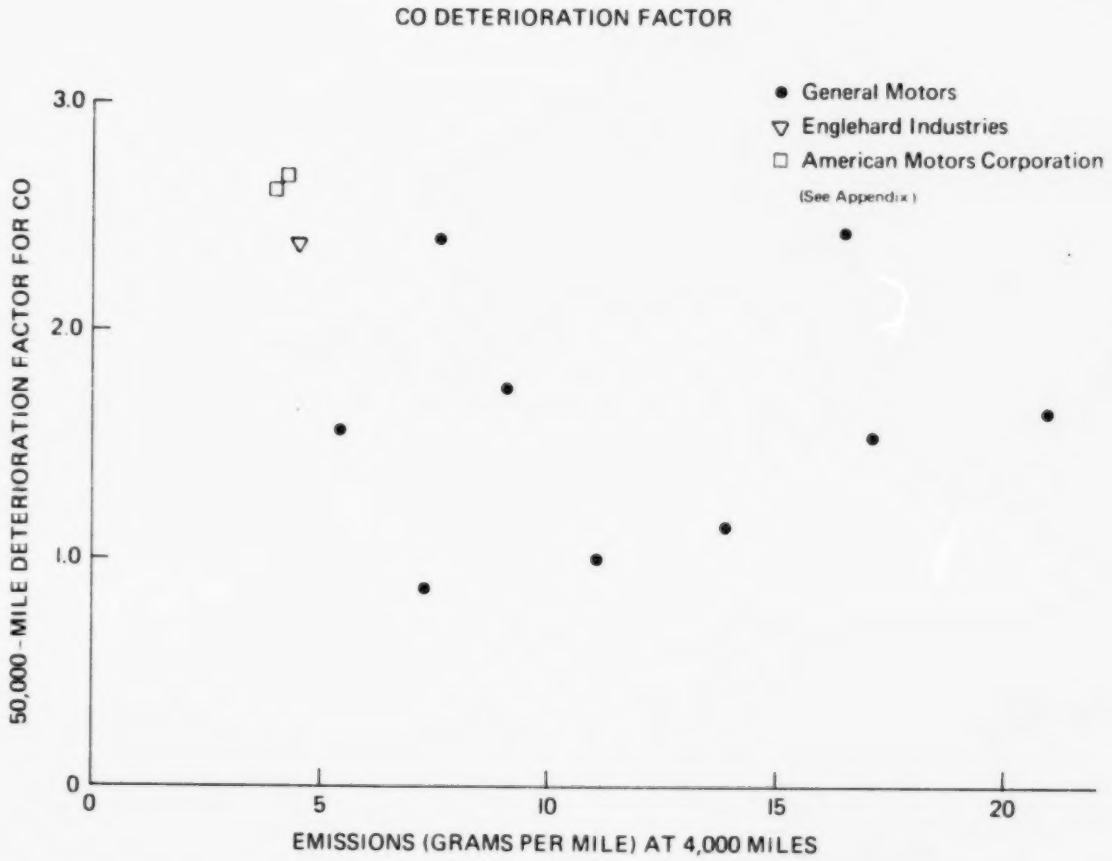
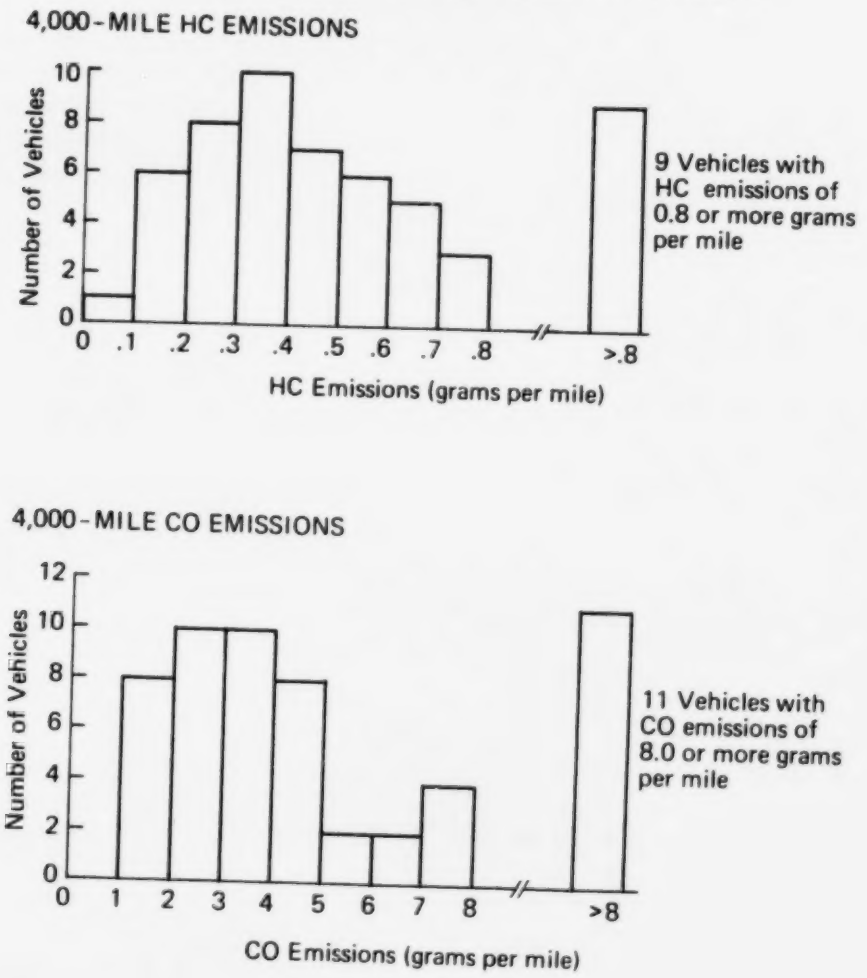

CO DETERIORATION FACTOR
General Motors
Englehard Industries
American Motors Corporation
(See Appendix)
50,000 - MILE DETERIORATION FACTOR FOR CO
3.0
2.0
1.0
0
0
5
10
15
20
EMISSIONS (GRAMS PER MILE) AT 4,000 MILES

FIGURE 3

EMISSIONS DATA FROM 55 PROMISING VEHICLES



APPENDIX

1. Sources of data for Figures 1 and 2:

    a. General Motors Request for Suspension of 1975 Federal Emission Standards, Section 4a, April 3, 1972.

    b. American Motors Corporation, submission to National Academy of Sciences, dated March 14, 1972.

    c. Technical Appendix to testimony of John G. Harlan, Jr., President, Englehard Industries, before the Senate Subcommittee on Air and Water Pollution, March 27, 1972.

2. Sources of data for 55 vehicles (Figure 3):

    a. General Motors Request for Suspension of 1975 Federal Emission Standards, Section 4a, April 3, 1972.

    b. American Motors Corporation, submission to National Academy of Sciences, dated March 14, 1972.

    c. Technical Appendix to testimony of John G. Harlan, Jr., President, Englehard Industries, before the Senate Subcommittee on Air and Water Pollution, March 27, 1972.

    d. Chrysler Corporation Application for Suspension of 1975 Motor Vehicle Emission Standards, Section IV, March, 1972.

    e. Ford Motor Company Application for Suspension of 1975 Motor Vehicle Exhaust Emission Standards, Volume 4, April 5, 1972.